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APPARATUS AND METHOD FOR VAPOR PHASE EPITAXY
[Kiso Seicho Sochi Oyobi Kiso Seicho Hoho]

Shiro Sakai, et al.

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INVENTORS	(72):	SAKAI, SHIRO; TAKAMATSU, YUKICHI; KOMIYA, YOSHINAO; KUREHA, REIJI; ISHIHAMA, YOSHIYASU; AMISHIMA, YUTAKA; SUZUKI, YOSHIKI; SASAKI, KOJI
APPLICANTS	(71):	JAPAN PIONICS K.K.; TOKUSHIMA SANSO KOGYO K.K.
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[Claims] /2*

[Claim 1] A vapor phase epitaxy apparatus for semiconductor films comprising a horizontal-type reaction tube equipped with:

a susceptor for mounting a substrate,

a heater for heating the substrate,

a raw material gas-introducing section that is arranged in such a way that the direction of the raw material gas introduced into the reaction tube is substantially parallel to the substrate, and

a reaction gas discharge section and

further with a pressurized gas-introducing section on the wall of the reaction tube facing the substrate,

wherein a part, at the least, of the pressurized gas-introducing section at the upstream-end part of the raw material gas passage is constructed in such a way that the pressurized gas is supplied obliquely downward or horizontally toward the downstream end of the raw material gas passage.

[Claim 2] The vapor phase epitaxy apparatus stated in Claim 1, wherein the surface of said pressurized gas-introducing section has a circular or elliptic shape.

[Claim 3] The vapor phase epitaxy apparatus stated in Claim 1, wherein the upstream-end portion of the pressurized gas-introducing section, which supplies the pressurized gas obliquely downward or

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horizontally toward the downstream end of the raw material gas passage, is formed in a semicircular shape, bow shape, fan shape, convex lens shape, or crescent shape.

[Claim 4] The vapor phase epitaxy apparatus stated in Claim 1, wherein the susceptor is configured to hold more than one substrate.

[Claim 5] The vapor phase epitaxy apparatus stated in Claim 1, wherein the susceptor is configured to hold a large size substrate of 4 inches or larger.

[Claim 6] The vapor phase epitaxy apparatus stated in Claim 1, wherein the gas passage in the raw material gas-introducing section is partitioned into an upper gas passage and a lower gas passage with a partition plate or a nozzle.

[Claim 7] The vapor phase epitaxy apparatus stated in Claim 1, wherein the upper gas passage of the raw material gas-introducing section is a passage for supplying a gas containing trimethylgallium, triethylgallium, trimethylindium, triethylindium, trimethylaluminum, or triethylaluminuml, and the lower gas passage is a passage for supplying ammonia, monomethylhydrazine, dimethylhydrazine, tert-butyl hydrazine, or trimethylamine.

[Claim 8] A method for vapor phase epitaxy comprising:

a step of mounting a substrate on a susceptor in a horizontal-type reaction tube,

a step of heating the substrate with a heater, and

a step of supplying a gas containing a raw material in a direction that is substantially parallel to the substrate and concurrently supplying the pressurized gas from the pressurized gas-introducing section provided on the reaction-tube wall facing the substrate, thereby epitaxially growing semiconductor film on said substrate,

said method being characterized by the fact that a part, at the least, of the pressurized gas that is fed from the part of the pressurized gas-introducing section at the upstream end of the raw material gas passage is supplied obliquely downward or horizontally toward the downstream end of the raw material gas passage, thereby implementing epitaxial growth.

[Claim 9] The method for vapor phase epitaxy stated in Claim 8, wherein the maximum heating temperature of said substrate is 1,000 °C or higher.

[Claim 10] The method for vapor phase epitaxy stated in Claim 8, wherein the vapor phase epitaxy is vapor phase epitaxy of a gallium nitride compound semiconductor, using trimethylgallium, triethylgallium, trimethylindium, triethylindium, trimethylaluminum, or triethylaluminium as the Group III metal source and ammonia, monomethylhydrazine, dimethylhydrazine, tert-butyl hydrazine, or trimethylamine as the nitrogen source.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention] The present invention relates to an apparatus and method for vapor phase epitaxy of semiconductor films. More specifically, the present invention relates to a vapor phase epitaxy apparatus and vapor phase epitaxy method that introduce a raw material gas from the gas-introducing section of a horizontal-type reaction tube, said section being arranged in such a way that the direction in which the raw material gas is supplied is substantially parallel to the substrate, and epitaxially grow a highly crystalline semiconductor film on the heated substrate uniformly and efficiently.

[0002]

[Related Art] In recent years, demand for a gallium nitride-based compound semiconductor for elements such as light emitting diode or laser diode has rapidly increased, particularly in the optical communication field. As a manufacturing method of gallium nitride-based compound semiconductor, there is known, for example, a method that, using an organometallic gas of, for example, trimethylgallium, trimethylindium, or trimethylaluminum as the Group III metal source and ammonia as the nitrogen source, epitaxially grows semiconductor film of gallium nitride-based compound on the surface of a substrate of sapphire or the like that has been set beforehand in a reaction tube.

[0003] As an apparatus for producing the aforesaid gallium nitride-based compound semiconductor, there is a vapor phase epitaxy apparatus that comprises a horizontal-type reaction tube equipped with a susceptor for mounting a substrate, a heater for heating the substrate, a raw material gas-introducing section that is arranged in such a way that the direction of the raw material gas introduced into the reaction tube is parallel to the substrate, and a reaction gas discharge section. With this vapor phase epitaxy apparatus having a horizontal-type reaction tube, semiconductor film is epitaxially grown on a substrate by mounting the substrate on the susceptor in the reaction tube, heating it with a heater, and subsequently supplying a gas containing a raw material in a direction that is parallel to the substrate.

[0004] In such a horizontal reaction tube, the raw material gas is dispersed by heat convention that occurs near the substrate and does not reach the substrate efficiently, thus presenting the problem of not yielding uniform and highly crystalline semiconductor film or of a slow growth rate. In recent years, however, there has been developed a vapor phase epitaxy apparatus or vapor phase epitaxy method that provides a pressurized gas-introducing section on the reaction-tube wall that faces the substrate and feeds a pressurized gas that does not affect the reaction of a carrier gas or the like into the reaction tube in a direction perpendicular to the substrate

so as to cause the flow of the raw material gas to change its direction and blow against the substrate. According to this technology, semiconductor film with good crystallinity is reportedly obtained by appropriately controlling the flow rate of the pressurized gas based on the kind and the flow rate of the raw material gas, the heating temperature of the substrate, and so forth.

[0005]

[Problems that the Invention Intends to Solve] However, with the aforesaid vapor phase epitaxy apparatus or vapor phase epitaxy method, because the gas flows that orthogonally intersect each other, in other words, the gas containing a raw material and the pressurized gas, are mixed on the substrate, the gas flows are easily disturbed and are /3 often difficult to control. In the case of, for example, implementing vapor phase epitaxy on a large-size substrate or on a plurality of substrates simultaneously, it is difficult to supply a raw material gas at a uniform concentration to a wide area on the substrate. Further, also in the case of implementing vapor phase epitaxy using the aforesaid trimethylgallium, trimethylindium, or trimethylaluminum as the raw material, the gas flows become complex on the substrate and are difficult to control because a high temperature of 1,000 °C or higher is required as the heating temperature of the substrate.

[0006] Accordingly, the objective of the present invention is to provide a vapor phase epitaxy apparatus and vapor phase epitaxy method

that, in implementing vapor phase epitaxy with the use of a horizontal-type reaction tube, are capable of epitaxially growing uniform and highly crystalline semiconductor film on a substrate efficiently even in the case of implementing vapor phase epitaxy on a large-size substrate or on a plurality of substrates simultaneously and also in the case of implementing vapor phase epitaxy by setting the vapor phase epitaxy temperature at a high temperature.

[0007]

[Means for Solving the Problems] The present inventors conducted extensive research so as to solve these problems and, as a result, learned that supplying a part, at the least, of the pressurized gas that is fed from the part of the pressurized gas-introducing section at the upstream end of the raw material gas passage obliquely downward or horizontally toward the downstream end of the raw material gas passage can alleviate the disturbance of the gas flows that occurs due to the mixing of the gas containing a raw material with the pressurized gas on the substrate.

[0008] Namely, the present invention is a vapor phase epitaxy apparatus for semiconductor films comprising a horizontal-type reaction tube equipped with: a susceptor for mounting a substrate, a heater for heating the substrate, a raw material gas-introducing section that is arranged in such a way that the direction of the raw material gas introduced into the reaction tube is substantially

parallel to the substrate, and a reaction gas discharge section and further with a pressurized gas-introducing section on the wall of the reaction tube facing the substrate, wherein a part, at the least, of the pressurized gas-introducing section at the upstream-end part of the raw material gas passage is constructed in such a way that the pressurized gas is supplied obliquely downward or horizontally toward the downstream end of the raw material gas passage.

[0009] Further, the present invention is also a method for vapor phase epitaxy comprising: a step of mounting a substrate on a susceptor in a horizontal-type reaction tube, a step of heating the substrate with a heater, and a step of supplying a gas containing a raw material in a direction that is substantially parallel to the substrate and concurrently supplying the pressurized gas from the pressurized gas-introducing section provided on the reaction-tube wall facing the substrate, thereby epitaxially growing semiconductor film on said substrate, said method being characterized by the fact that a part, at the least, of the pressurized gas that is fed from the part of the pressurized gas-introducing section at the upstream end of the raw material gas passage is supplied obliquely downward or horizontally toward the downstream end of the raw material gas passage, thereby implementing epitaxial growth.

[0010]

[Preferred Mode of the Invention] The vapor phase epitaxy apparatus and vapor phase epitaxy method of the present invention are applicable to a vapor phase epitaxy apparatus and vapor phase epitaxy method that epitaxially grow semiconductor film on a substrate by mounting the substrate on a susceptor in a horizontal-type reaction tube, heating the substrate with a heater, and subsequently supplying a gas containing a raw material in a direction that is parallel to the substrate as well as a pressurized gas from the pressurized gas-introducing section on the reaction-tube wall facing the substrate.

[0011] The vapor phase epitaxy apparatus of the present invention is configured in such a way that a part, at the least, of the pressurized gas-introducing section at the upstream end of the raw material gas passage supplies the pressurized gas obliquely downward or horizontally toward the downstream end of the raw material gas passage. The vapor phase epitaxy method of the present invention is a vapor phase epitaxy method in which a part, at the least, of the pressurized gas that is fed from the part of the pressurized gas-introducing section at the upstream end of the raw material gas passage is supplied obliquely downward or horizontally toward the downstream end of the raw material gas passage, thereby implementing epitaxial growth.

[0012] In the vapor phase epitaxy apparatus and vapor phase epitaxy method of the present invention, the kind, size, and quantity

of the substrate or the kind, flow rate, and the like of the raw material gas are not specifically limited. However, with respect to the substrate, especially in the case of implementing vapor phase epitaxy on a large-size substrate of 4 inches or larger or implementing vapor phase epitaxy simultaneously on six pieces of substrates, the effects of the present invention will be fully demonstrated in that the disturbance of the gas or diffusion of the raw material gas caused by heat convection can be alleviated over an extended area of the substrate. Typical examples of the substrate are sapphire, SiC, bulk galliumnitride, and the like.

[0013] Furthermore, with respect to the kind of the raw material gas, especially in the case of implementing vapor phase epitaxy that requires a 1.000 °C or higher substrate heating temperature, the effects of the present invention will be fully demonstrated in that the gas disturbance and diffusion of the raw material gas caused by vigorous heat convection on the substrate can be alleviated. A typical example of vapor phase epitaxy that uses this type of raw material is the vapor phase epitaxy of gallium nitride-based compound semiconductor with the use of trimethylgallium, triethylgallium, trimethylindium, triethylindium, trimethylaluminum, or triethylaluminium as the Group III metal source and ammonia, monomethylhydrazine, dimethylhydrazine, tert-butyl hydrazine, or trimethylamine as the nitrogen source.

[0014] The following will explain the vapor phase epitaxy apparatus of the present invention in detail, referring to Figs. 1 through 3, but the present invention is not restricted by these. Fig. 1 is a vertical sectional view illustrating an example of the vapor phase epitaxy apparatus of the present invention. As shown in Fig. 1, the vapor phase epitaxy apparatus of the present invention comprises a horizontal-type reaction tube (1) equipped with a substrate (2), a susceptor (3) for mounting and rotating the substrate, a heater (4) for heating the substrate, a raw material gas-introducing section (5) that is arranged in such a way that the feeding direction of the raw material gas into the reaction tube becomes substantially parallel to the substrate, and a reaction gas discharge section (6) and further equipped with a pressurized gas-introducing section (7) on the reaction-tube wall that faces the substrate, and a part (9), at the least, of the pressurized gas-introducing section (7) at the upstream end of the raw material gas passage is constructed in such a way that the pressurized gas is supplied obliquely downward or horizontally toward the downstream end of the raw material gas passage. /4

[0015] In the vapor phase epitaxy apparatus of the present invention, the pressurized gas-introducing section (7) is disposed at a position in which the flow of the gas containing the raw material gas, receives the influence of the heat generated by the heater. Therefore, although the position of the pressurized gas-introducing

section (7) cannot be determined unconditionally because it depends on the flow rate of the gas containing the raw material gas, location of the heater, vapor phase epitaxy temperature, and the size, shape, or the like of the horizontal-type reaction tube, it is usually arranged so that the center of the pressurized gas-introducing section comes close to the position (12) corresponding to the center of the susceptor. Further, the surface (or the cross-section in the direction of the raw material gas passage) of the pressurized gas-introducing section is usually circular or elliptic, and its area is about 0.5 to 5 times the cross-sectional area, in the direction of the raw material gas passage, of the susceptor.

[0016] In the case of growing semiconductor film by vapor phase epitaxy using a horizontal-type reaction tube, like the one used in this invention, it is desirable to feed a pressurized gas into the reaction tube from the pressurized gas-introducing section. However, when the flow rate of the pressurized gas is small, the pressurized gas could have a lower effect of preventing the diffusion of the raw material gas caused by heat convection near the substrate, and, when the flow rate of the pressurized gas is large, the vapor phase epitaxy of semiconductor film on the substrate could be adversely affected. According to the present invention, however, the pressurized gas located at the upstream-end portion of the raw material gas passage is fed obliquely downward or horizontally toward the downstream end of

the raw material gas passage; therefore, it becomes possible to eliminate the aforesaid problems and thereby to efficiently form uniform and highly crystalline semiconductor film on a substrate by vapor phase epitaxy.

[0017] Fig. 2 contains cross-sectional views illustrating examples of the configuration of the pressurized gas-introducing section (9) that is constructed to feed the pressurized gas obliquely downward or horizontally toward the downstream end of the raw material gas passage in the vapor phase epitaxy apparatus of the present invention. In the present invention, the structure or the like of the device, the outlets of the pressurized gas-introducing section, and so forth that are used for supplying the pressurized gas obliquely downward or horizontally are not specifically limited, and, for example, device 13 may be attached to each outlet, as illustrated in Figs. 2(A) and 2(B), or the outlets may have the configuration shown in Fig. 2(C). Incidentally, it is not essential for all of the outlets in the pressurized gas-introducing section (9) to be so configured to feed the pressurized gas obliquely downward or horizontally, and, as illustrated in Fig. 2(D), outlets of this type may be provided together with gas outlets for feeding the pressurized gas straight downward to the substrate.

[0018] Fig. 3 shows examples of the section in which are provided the gas outlets for feeding the pressurized gas obliquely downward or

horizontally in the pressurized gas-introducing section of the present invention. (In Fig. 3, the flowing direction of the raw material gas is from left to right.) In the vapor phase epitaxy apparatus according to the present invention, the setup section for the gas outlets that are configured as described in the foregoing may be, as shown in Fig. 3(A), in the shape of the shaded part of the semicircular sections that are formed by equally dividing the pressurized gas-introducing section into the upstream end part and downstream end part. In addition, it may be the shaded bow-shape section in Fig. 3(B), shaded fan-shape section in Fig. 3(C), shaded convex lens-shape section in Fig. 3(D), or shaded crescent-shape section in Fig. 3(E).

[0019] Further, as shown in Fig. 3(F), the outlets may be distributed in such a manner that the feeding direction of the pressurized gas is changed from the horizontal direction to the vertical direction in stages or continuously, starting from the upstream end toward the downstream end. Furthermore, the outlets may be distributed in such a manner that the ratio of the outlets that feed the pressurizing gas obliquely downward or horizontally is varied in stages or continuously. With this type of outlet distribution, it becomes possible to change the feeding direction of the pressurized gas smoothly from the horizontal direction to vertical direction.

[0020] Further, in the vapor phase epitaxy apparatus of the present invention, the pressurized gas-introducing section (9) for

feeding the pressurized gas obliquely downward or horizontally is usually positioned adjacent to the pressurized gas-introducing section (8) for feeding the pressurized gas downward toward the substrate, as shown in Fig. 1. However, the present invention is not limited to this configuration, and the pressurized gas-introducing section (9) may be positioned separately from the pressurized gas introducing section (8), for example, by 1 to 5 cm toward the upstream end of the raw material gas passage.

[0021] The material for constructing the pressurized gas-introducing section in the vapor phase epitaxy apparatus of the present invention is not particularly limited, but a quartz plate with micropores, on which decomposition products or reaction products of the raw material gas do not deposit easily, is usually employed. The diameter of the micropores is not particular limited. However, pores with an excessively large diameter could cause the gas flow from the microporous section to become uneven, while excessively fine pores lead to a large pressure loss, thus making it difficult to obtain a desired gas flow rate. For these reasons, the diameter is usually within the range of 0.1 to 3 mm or thereabouts, preferably within the range of from 0.3 to 2 mm or thereabouts.

[0022] The configuration of the pressurized gas-introducing section in the present invention is applicable either to a vapor phase epitaxy apparatus having a structure in which the raw material gas-

introducing section has one gas supply port or a vapor phase epitaxy apparatus having a structure in which the gas flow passage of the raw material gas-introducing section is partitioned into an upper gas passage and lower gas passage by a partition plate or nozzle. A typical example of the structure in which a partition plate or nozzle is used to partition the gas passage into an upper gas passage and lower gas passage is a vapor phase epitaxy apparatus in which the upper gas passage of the raw material gas-introducing section is used for supplying a gas containing trimethylgallium, triethylgallium, trimethylindium, triethylindium, trimethylaluminum, or triethylaluminium, and the lower gas passage is used for supplying ammonia, monomethylhydrazine, dimethylhydrazine, tert-butyl hydrazine, or trimethylamine.

[0023] Next, the vapor phase epitaxy method of the present invention will be described in detail. The present invention provides a vapor phase epitaxy method that, using the aforesaid vapor phase epitaxy apparatus of the present invention, epitaxially grows semiconductor film on a substrate by supplying a gas containing a raw material in a direction that is substantially parallel to the substrate and concurrently supplying a pressurized gas from the pressurized gas-introducing section that is positioned on the reaction-tube wall that faces the substrate, said method being characterized by the fact that a part, at the least, of the

pressurized gas that is fed from the part of the pressurized gas-introducing section at the upstream end of the raw material gas passage is supplied obliquely downward or horizontally toward the downstream end of the raw material gas passage, thereby implementing epitaxial growth. /5

[0024] In the vapor phase epitaxy method of the present invention, the flow rate of the pressurized gas fed from the pressurized gas-introducing section should be regulated so as to suppress the diffusion of the raw material gas caused by heat convection that occurs near the substrate and also so as not to adversely affect the vapor phase epitaxy of semiconductor film on the substrate. Preferably, it is regulated so as to allow the gas containing a raw material gas that is supplied from the raw material gas-introducing section to pass through over the substrate without changing its direction. Therefore, although the feeding direction and flow rate of the pressurized gas cannot be determined unconditionally because they depend on the location of the heater, the temperature of vapor phase epitaxy, the size or shape of the horizontal-type reaction tube, and so forth, the mean feeding direction of the pressurized gas at the upstream-end part of the raw material gas passage is at an angle from 15 to 75 degrees in relation to the direction of the raw material gas passage, and the average flow rate of the pressurized gas per area that is equal to the substrate surface area is from 1/30 to 1/3, preferably from 1/10 to

1/4, or thereabouts of the flow rate of the gas containing the raw material. The term "substrate surface area" used herein means the area that is surrounded by the outermost trajectory that the edge of the substrate draws during the vapor phase epitaxy operation. The pressurized gas employed in the vapor phase epitaxy method of the present invention is not limited specifically and may be any gas that does not adversely affect the vapor phase epitaxy reaction, examples of which include inert gases, such as helium, argon, and the like, as well as hydrogen, nitrogen, and so forth.

[0025] In the vapor phase epitaxy method of the present invention, it is desirable to cause the substrate to rotate on its own axis and/or revolve for efficient vapor phase epitaxial growth of homogeneous semiconductor film on the substrate. Moreover, the vapor phase epitaxy method of the present invention is widely applicable to vapor phase epitaxy conducted at a temperature ranging from a relatively low temperature of about 600 °C as the highest heating temperature of the substrate to a relatively high temperature of 1,000 °C or higher. The internal pressure of the horizontal-type reaction tube in the vapor phase epitaxy method of the present invention may be normal pressure or reduced pressure, or the tube may be pressurized to, for example, 0.1 MPa/cm^2 G.

[0026] In the present invention, the term "raw material gas" used herein means a gas that serves as the source of the element that is

captured into crystals as the crystal constituent element during crystal growth. The kind of raw material gas used for vapor phase epitaxy varies according to the kind of semiconductor film to be formed, and, for example, metal hydrides, such as arsin, phosphine, silane, and the like; organometallic compounds, such as trimethylgallium, trimethylindium, trimethylaluminum, and the like; ammonia; hydrazine; alkyl amine; and so forth are employed. Further, as a gas containing a raw material gas, a gas that is prepared by diluting a raw material gas with a gas, such as hydrogen, helium, argon, nitrogen, or the like, may be used.

[0027]

[Embodiments] The following will explain the present invention in concrete terms by presenting embodiments, but it is to be understood that these embodiments do not limit or restrict the scope of the present invention.

[0028] Example 1

[Production of a vapor phase epitaxy apparatus] A vapor phase epitaxy apparatus was prepared that had a structure similar to the vapor phase epitaxy apparatus shown in Fig. 1 and that was comprised of a quartz-made, horizontal-type reaction tube [which was, in terms of inside dimensions, 280 mm wide (a pressurized gas-introducing section), 20 mm high, and 1,500 mm long]. The susceptor and the heater were circular and had an outside diameter of 260 mm, and they were

made to process six 2-inch substrates simultaneously with one piece mounted at the center of the susceptor and five pieces with equal spacing along the periphery of the susceptor.

[0029] Further, as the pressurized gas-introducing section having a circular surface was prepared an introducing section comprised of a quartz glass sintered compact that was constructed in such a way as to feed the pressurized gas horizontally from a bow-shaped section, like the one shown in Fig. 2(B), the area of the bow-shaped section being 1/10 the area of the entire pressurized gas-introducing section. Furthermore, the feeding amount of the pressurized gas per unit area of the pressurized gas-introducing section at every point was set to be the same. Moreover, the area of the microporous section of the pressurized gas-introducing section was 2 times the area of the substrate.

[0030] (Vapor phase epitaxy experiment) With this apparatus, crystal growth of GaN on sapphire substrates having a diameter of 2 inches was carried out as follows. The sapphire substrates were mounted on the susceptor, and the interior of the reaction tube was purged with hydrogen gas. Thereafter, while hydrogen gas was fed at 65 L/minute from the upper gas passage of the raw material gas-introducing section and, concurrently, hydrogen gas was fed at 20 L/minute through the microporous section of the pressurized-gas-

introducing section, the substrates were heated to 1,150 °C and heat-treated for 10 minutes.

[0031] Next, the reaction temperature of the substrates was decreased to 500 °C, and the reaction system was left standing until it stabilized. Subsequently, a gas mixture of ammonia and hydrogen (ammonia: 40 L/min, hydrogen: 10 L/min) was supplied from the lower gas passage of the raw material gas-introducing section, and a hydrogen gas containing trimethylgallium (trimethylgallium: 240 μmol/minute, hydrogen 50 L/minute) was supplied from the upper gas passage. Concurrently, nitrogen gas was fed at a rate of 50 L/minute through the pressurized gas-introducing section. Under this condition, low-temperature vapor phase epitaxy of GaN was carried out for five minutes.

[0032] After a low-temperature grown layer was formed, the feeding of trimethylgallium was terminated, and the temperature was increased to 1,100 °C, under which condition the reaction system was left standing until it stabilized. Then, a hydrogen gas containing trimethylgallium (trimethylgallium: 240 μmol/minute, hydrogen 50 L/min) was supplied again from the upper gas passage, and nitrogen gas was continued to be fed at 50 L/min through the microporous section, under which condition vapor phase epitaxy of GaN was implemented for 60 minutes. During this process, the susceptor was rotated at 12 turns

per minute and the substrates at 36 turns per minute. In this manner, the vapor phase epitaxy was repeated five times.

[0033] (GaN film evaluation and the like)

After the completion of the vapor phase epitaxy, the presence or absence of solid matter adhering to the reaction-tube wall facing the substrates was checked. As a result, no adhesion of solid matter was found. Further, the substrates were taken out from the apparatus, and the distribution of the GaN film thickness was measured to evaluate uniformity. Since the substrates rotated on their own axes during the vapor phase epitaxy, the distribution of the film thickness was measured from the center of each substrate to the edge. The film thickness and its fluctuation range [(maximum value - minimum value)/ mean value] of one substrate mounted at the center of the susceptor and those of five substrates mounted at the periphery were measured, and the results are shown in Table 1. Furthermore, in order to evaluate the crystalline quality and electrical characteristics of the grown film, the six substrates were subjected to X-ray diffraction [half-value width of the (002) face] and hole measurement (mobility), and the results are shown in Table 1. Here, the numeric values /6 regarding the substrates mounted at the periphery are mean values of the five substrates, and the same is true for Example 2 and those that follow.

[0034] Example 2

A vapor phase epitaxy apparatus with the same structure as Example 1 was produced, except that the pressurized gas-introducing section was replaced by a pressurized gas-introducing section that was comprised of a quartz glass sintered compact that was constructed in such a way as to feed the pressurized gas horizontally from a convex lens-shape section, like the one shown in Fig. 2(D). (The convex lens-shape section was defined by the trajectory of a circle having its center outside the circumference of the pressurized gas-introducing section and being the same size as the pressurized gas-introducing section and by the circumference of the pressurized gas-introducing section, and the area of the convex lens-shape section was 1/10 the area of the entire pressurized gas-introducing section.) Except that this vapor phase epitaxy apparatus was used, a vapor phase epitaxy experiment and GaN film evaluation and the like were carried out in the same manner as in Example 1. The results are shown in Table 1.

[0035] Example 3

A vapor phase epitaxy apparatus with the same structure as Example 1 was produced, except that the pressurized gas-introducing section was replaced by a pressurized gas-introducing section that was comprised of a quartz glass sintered compact that had a bow-shape section having 2 times the area of the section in Example 1 and that was constructed in such a way as to feed the pressurized gas at an angle of 45 degrees from the horizontal direction. Except that this

vapor phase epitaxy apparatus was used, a vapor phase epitaxy experiment and GaN film evaluation and the like were carried out in the same manner as in Example 1. The results are shown in Table 1.

[0036] Example 4

A vapor phase epitaxy apparatus with the same structure as Example 1 was produced, except that the pressurized gas-introducing section was replaced by a pressurized gas-introducing section that was comprised of a quartz glass sintered compact that was constructed in such a way as to feed the pressurized gas by changing its feed direction from the horizontal direction to vertical direction in stages, starting from the upstream end toward the downstream end, as shown in Fig. 2(F). (The feed directions of the pressurized gas were 60 degrees and 30 degrees from the horizontal direction, and the area of the convex lens-shape section was 1/10 the area of the entire pressurized gas-introducing section.) Except that this vapor phase epitaxy apparatus was used, a vapor phase epitaxy experiment and GaN film evaluation and the like were carried out in the same manner as in Example 1. The results are shown in Table 1.

[0037] Comparative example 1

A vapor phase epitaxy apparatus with the same structure as Example 1 was produced, except that the pressurized gas-introducing section was replaced by a pressurized gas-introducing section that was comprised of a quartz glass sintered compact that was constructed in

such a way as to feed the pressurized gas downward toward the substrates from the entire gas-introducing section. Except that this vapor phase epitaxy apparatus was used, a vapor phase epitaxy experiment and GaN film evaluation and the like were carried out in the same manner as in Example 1. The results are shown in Table 1.

[0038]

[Table 1]

	(c) 押圧ガス導入部	(d) 押圧ガス供給方向	(e) 基板位置	(f) 膜厚 (μm)	(g) 変動幅 (%)	(h) 半値幅 [arcsec]	(i) 移動度 (cm²/vs)	(j) 固形物の付着
実施例1 (a)	図2 (B) (k) (1/10)	水平方向 (l)	中心 (o)	.24	1	318	204	無 (q)
			周辺 (p)	.15	2	309	207	
実施例2 (a)	図2 (D) (k) (1/10)	水平方向 (l)	中心 (o)	.23	1	280	209	無 (q)
			周辺 (p)	.31	1	272	202	
実施例3 (a)	図2 (B) (k) (1/5)	45度 (m)	中心 (o)	.13	2	321	192	無 (q)
			周辺 (p)	.09	1	328	201	
実施例4 (a)	図2 (F) (k) (1/5)	30、60度 (m)	中心 (o)	.32	1	271	215	無 (q)
			周辺 (p)	.26	1	277	213	
比較例1 (b)		垂直方向 (n)	中心 (o)	.93	2	350	183	無 (q)
			周辺 (p)	.86	2	366	188	

Key: a) example; b) comparative example; c) the pressurized gas-introducing section; d) feed direction of the pressurized gas; e) substrate position; f) film thickness; g) fluctuation range; h) half value width; i) mobility; j) adhesion of solid matter; k) Fig. 2; l) horizontal direction; m) degree angle; n) vertical direction; o) center; p) periphery; q) none.

* The numbers inside the parentheses under the column "the pressurized gas-introducing section" each indicate the ratio of the area of the section for feeding the pressurized gas obliquely downward or horizontally.

[0039] The results shown in the foregoing confirmed that, with the vapor phase epitaxy apparatus and vapor phase epitaxy method of the present invention, uniform GaN film having excellent electrical

characteristics was obtained in the vapor phase epitaxy of GaN, which requires a temperature of 1,000 °C or higher, without being affected by the position of the substrates, that is, irrespective of whether they were mounted at the center or at the periphery of the susceptor.

[0040]

[Effects of the Invention] The vapor phase epitaxy apparatus and vapor phase epitaxy method of the present invention, in implementing vapor phase epitaxy with the use of a horizontal-type reaction tube, makes it possible to efficiently grow uniform and highly crystalline semiconductor film epitaxially on a substrate even in the case of implementing vapor phase epitaxy on a large-size substrate or on a plurality of substrates simultaneously and also in the case of implementing vapor phase epitaxy at a high temperature.

[Brief Explanation of the Drawings]

[Fig. 1] A vertical sectional drawing illustrating one embodiment of the vapor phase epitaxy apparatus of the present invention.

[Fig. 2] Vertical sectional drawings illustrating examples of the structure of the pressurized gas-introducing section for feeding the pressurized gas obliquely downward or horizontally.

[Fig. 3] Horizontal plan drawings illustrating distribution examples of the pressurized gas-introducing section for feeding the pressurized gas obliquely downward or horizontally and the pressurized

gas-introducing section for feeding the pressurized gas downward toward substrates.

[Explanation of the Reference Symbols]

1. Horizontal-type reaction tube

2. Substrate

3. Susceptor

4. Heater

5. Raw material gas-introducing section

6. Reaction gas discharge section

7. Pressurized gas-introducing section

8. Pressurized gas-introducing section for feeding the pressurized gas downward toward substrates

9. Pressurized gas-introducing section for feeding the pressurized /7 gas obliquely downward or horizontally

9a. Pressurized gas-introducing section for feeding the pressurized gas nearly in a horizontal direction

9b. Pressurized gas-introducing section for feeding the pressurized gas obliquely downward

10. Pressurized gas feed pipe

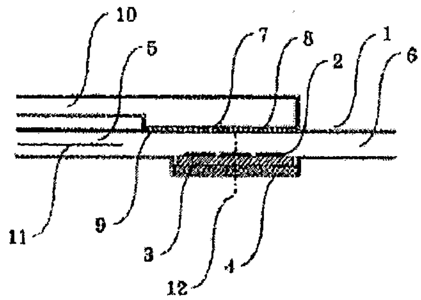
11. Partition plate

12. The position corresponding to the center of the susceptor

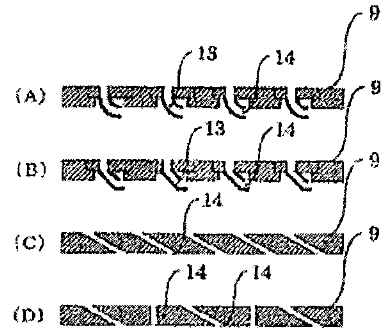
13. A device for feeding the pressurized gas obliquely downward or horizontally

14. Pressurized gas outlet

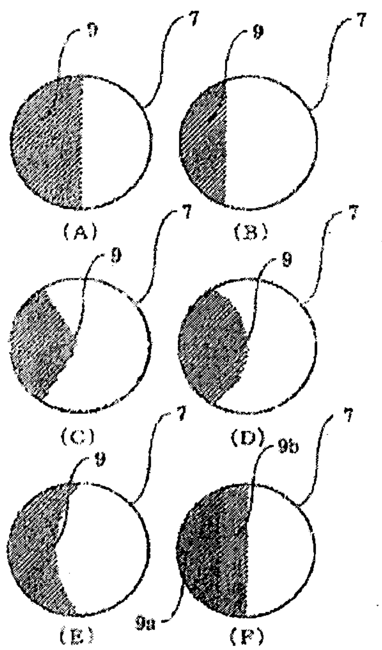
[FIG. 1]



[FIG. 2]



[FIG. 3]



Zervigon, Rudy

From: Yasuko Burgett [yburgett@flstranslation.com]
Sent: Monday, December 17, 2007 9:53 AM
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Cc: Zervigon, Rudy
Subject: 08-1360
Attachments: 08-1360.doc

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Yasuko Burgett
FLS, Inc.
(256) 881-1120 Tel
(256) 880-1112 Fax
YBurgett@FLStranslation.com